CLAIMS

We claim:

1. An apparatus for the real-time, in-line testing of a semiconductor wafer during semiconductor processing, said apparatus comprising:

a head assembly comprising:

a modulated light source exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency; and

a voltage sensor detecting a surface photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source without contacting said wafer; and

a conveying apparatus conveying said wafer adjacent said voltage sensor of said head assembly during said semiconductor processing.

2. The apparatus of claim 1 wherein said wafer and said head assembly are in continuous relative motion during said detection of said surface photovoltage by said voltage sensor.

3. The apparatus of claim 1 wherein said head assembly has a longitudinal axis and the orthogonality of said longitudinal axis of said head assembly with respect to said surface of said wafer is adjustable.

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4. The apparatus of claim 3 wherein said orthogonality of said longitudinal axis is adjustable manually by set screws.

5. The apparatus of claim 3 wherein said orthogonality of said longitudinal axis is adjustable automatically by actuators.

6. The apparatus of claim 2 wherein said head assembly is stationary and said wafer is moved continuously relative to said head assembly.

7. The apparatus of claim 6 wherein said conveying apparatus is a conveyor belt.

8. The apparatus of claim 6 wherein said conveying apparatus is a robotic arm.

9. The apparatus of claim 6 wherein said conveying apparatus is a wafer chuck.

10. The apparatus of claim 9 wherein said wafer chuck is insulated from said wafer and is grounded.

11. The apparatus of claim 6 wherein said conveying apparatus conveys said wafer beneath said voltage sensor of said head assembly.

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12. The apparatus of claim 1 wherein said conveying apparatus is biased by a DC voltage.

13. The apparatus of claim 12 wherein said bias DC voltage is substantially between -1000 and 1000 volts.

14. The apparatus of claim 1 wherein said conveying apparatus conveys said wafer above said voltage sensor of said head assembly.

15. The apparatus of claim 1 further comprising:

a light splitting device positioned between said modulated light source and said wafer, said light splitting device passing a first portion of said modulated light from said modulated light source onto said wafer; and

a position photodiode positioned to receive light reflected by said wafer and reflected by said light splitting device,

said position photodiode producing a location signal in response to said wafer reflecting said modulated light.

16. The apparatus of claim 15 wherein said light splitting device is a beam splitter.

17. The apparatus of claim 15 wherein said position photodiode detects the edge of said wafer by said reflected light and said voltage sensor measures said surface photovoltage in response to said location signal.

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18. The apparatus of claim 15 further comprising a collimating lens collimating said modulated light from said modulated light source.

19. The apparatus of claim 18 wherein said collimating lens is positioned between said modulated light source and said light splitting device.

20. The apparatus of claim 1 further comprising:

a position sensor providing electrical signals in response to to the position of said head assembly relative to said wafer; and

a head assembly positioner moving said head assembly toward and away from said wafer in response to electrical signals received from said position sensor indicating the position of said head assembly relative to said wafer.

21. The apparatus of claim 20 wherein said position sensor comprises at least one position electrode and said surface photovoltage sensor comprises a surface photovoltage electrode in electrical communication with a surface photovoltage preamplifier.

22. The apparatus of claim 21 wherein said surface photovoltage electrode is connected to said surface photovoltage preamplifier by at least one flexible contact.

23. The apparatus of claim 21 wherein an approximately 70 kHz signal is supplied to said at least one position electrode.

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24. The apparatus of claim 1 wherein said modulated light source is a light emitting diode (LED).

25. The apparatus of claim 24 wherein said modulated light source is modulated at approximately 40 kHz.

26. The apparatus of claim 21 further comprising:

an insulator having a first side and a second side and at least one side wall connecting said first side and said second side,

wherein said surface photovoltage electrode is deposited upon the first side of said insulator.

27. The apparatus of claim 26 wherein a contact electrode is deposited on said second side of said insulator, said contact electrode in electrical communication with said surface photovoltage electrode by conductors deposited on said side wall between said contact electrode and said surface photovoltage electrode.

28. The apparatus of claim 26 wherein said surface photovoltage electrode is covered with a thin insulated coating.

29. The apparatus of claim 28 wherein said thin insulating coating is thinner than the distance between the voltage electrode and said wafer during said detection of said surface photovoltage.

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30. The apparatus of claim 21 further comprising:

an insulator having a first side and a second side and at least one side wall connecting said first side and said second side,

wherein said at least one position electrode is deposited upon said first side of said insulator.

31. The apparatus of claim 30 wherein at least one contact electrode is deposited on said second side of said insulator, said at least one contact electrode in electrical communication with a respective one of said at least one position electrode by conductors deposited on said side wall between each said at least one contact electrode and said respective one of said at least one position electrode.

32. The apparatus of claim 30 wherein said at least one position electrode is covered with a thin insulated coating.

33. The apparatus of claim 20 further comprising:

a computer comprising a data acquisition circuit and a position control circuit;

a position measuring circuit in electrical communication with said data acquisition circuit and in electrical communication with said position sensor; and

a surface photovoltage measuring circuit in electrical communication with said data acquisition circuit, in electrical

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communication with said modulated light source and in electrical communication with said surface photovoltage sensor,

said head assembly positioner moving said head assembly toward and away from said wafer in response to signals from said position control circuit, generated in response to said signal from said position measuring circuit,

said computer determining electrical characteristics of said wafer in response to said signals acquired by said data acquisition circuit from said surface photovoltage measuring circuit.

34. The apparatus of claim 33 wherein said position measuring circuit comprises:

a lock-in amplifier having an input terminal, a reference terminal and an output terminal; and

an oscillator in electrical communication with said position sensor and in electrical communication with said reference terminal of said lock-in amplifier,

said position sensor in electrical communication with said ~~input terminal of said lock-in amplifier,~~

said output terminal of said lock-in amplifier in electrical communication with said data acquisition circuit.

35. The apparatus of claim 33 wherein said surface photovoltage measuring circuit comprises:

a lock-in amplifier having an input terminal, a reference terminal and an output terminal; and

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an oscillator in electrical communication with said modulated light source and in electrical communication with said reference terminal of said lock-in amplifier,

said voltage sensor in electrical communication with said input terminal of said lock-in amplifier;

said output terminal of said lock-in amplifier in electrical communication with said data acquisition circuit.

36. The apparatus of claim 35 wherein said surface photovoltage measuring circuit further comprises said position sensor in electrical communication with electrical ground.

37. The apparatus of claim 1 further comprising a corona source charging said wafer to form an inversion layer prior to moving said wafer adjacent said surface photovoltage sensor.

38. The apparatus of claim 37 wherein said corona source comprises a control loop to prevent the overcharging of said wafer.

39. The apparatus of claim 37 further comprising a charge neutralizing device for discharging said wafer after said voltage sensor has measured said surface photovoltage.

40. A method for the real-time, in-line testing of a semiconductor wafer during semiconductor processing, said method comprising the steps of:

conveying said wafer such that a surface of said wafer is substantially parallel to a surface photovoltage electrode of a head assembly during said semiconductor processing;

exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency; and

detecting with said surface photovoltage electrode a photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source.

41. The method of claim 40 further comprising the step of forming an inversion layer at said wafer surface prior to exposing said wafer to said light of a predetermined wavelength.

42. The method of claim 41 wherein said step of forming an inversion layer is accomplished by applying a corona to said wafer prior to conveying said wafer such that said wafer surface is substantially parallel to said surface photovoltage sensor of said head assembly.

43. The method of claim 42 further comprising the step of controlling the charging of said wafer by said corona in response to a potential measured on said wafer.

44. The method of claim 41 wherein said step of forming an inversion layer is accomplished by applying a high voltage to said surface photovoltage sensor once said wafer is conveyed such that

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said wafer surface is substantially parallel to said surface photovoltage sensor of said head assembly.

45. The method of claim 41 wherein said step of forming an inversion layer is accomplished by exposing said wafer to hydrogen fluoride prior to conveying said wafer such that said surface of said wafer is substantially parallel to said surface of said photovoltage sensor of said head assembly.

46. The method of claim 45 wherein said wafer is a p-type silicon wafer.

47. A method for the real-time, in-line testing of a semiconductor wafer during semiconductor processing, said method comprising the steps of:

moving said wafer until said wafer crosses a beam of intensity modulated light from an LED in a head assembly;

repeatedly measuring the light reflected by said wafer until the difference between sequential values is less than substantially 5%;

exposing said wafer to a modulated light beam of a predetermined wavelength and frequency;

measuring a surface photovoltage signal produced in response to said modulated light beam with a surface photovoltage electrode;

measuring capacitance signals from position electrodes; and

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if capacitance signals from different position electrodes differ by more than substantially 5%, not recalculating previous values of said surface photovoltage signal; and

if capacitance signals from different position electrodes differ by less than substantially 5% recalculating previous values of said surface photovoltage signal.

48. A method of restoring a doping concentration at the surface of a wafer by exposing said wafer to a high intensity illumination.

49. The method of claim 48 in which said high intensity illumination is provided by a 250 W halogen light source.

50. An apparatus for the real-time, in-line testing of the front surface and the back surface of a semiconductor wafer during semiconductor processing, said apparatus comprising:

two head assemblies, each head assembly comprising:

a modulated light source exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency; and

a surface photovoltage sensor detecting a photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source without contacting said wafer; and

a conveying apparatus conveying said wafer such that each respective surface of said wafer is parallel with the surface of a respective one of said surface photovoltage sensors such that said

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surface photovoltage sensor of one head assembly measures said surface photovoltage induced on one surface of said wafer and said surface photovoltage sensor of the other head assembly measures said surface photovoltage induced on the other surface of said wafer.

51. The apparatus of claim 50 wherein said wafer and said head assemblies in continuous relative motion during said detection of said surface photovoltage by said surface photovoltage sensor.

52. The apparatus of claim 51 wherein said surface photovoltage induced in each surface of said wafer is measured by said respective head assembly substantially simultaneously.

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53. A semiconductor wafer fabrication system comprising:

a sealed chamber for processing said semiconductor wafer; and

a head assembly comprising:

a modulated light source exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency; and

a surface photovoltage sensor detecting a surface photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source without contacting said wafer,

said surface voltage sensor of said head assembly located within said sealed chamber.

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54. The semiconductor wafer fabrication system of claim 53 wherein said sealed chamber is a reduced pressure chamber.

55. The semiconductor wafer fabrication system of claim 53 wherein said sealed chamber is a chemically reactive gas chamber.

56. The semiconductor wafer fabrication system of claim 53 wherein said sealed chamber is an inert environment chamber.

57. The semiconductor wafer fabrication system of claim 53 wherein said head assembly is entirely located within said sealed chamber.

58. A method for correcting for the intensity of light absorbed by a wafer comprising the steps of:

exposing a reflective surface having a known reflectivity to a light of a predetermined wavelength and modulated at a predetermined frequency;

measuring the intensity of said light reflected by said reflective surface;

exposing said wafer to said light of a predetermined wavelength and modulated at a predetermined frequency;

measuring the intensity of said light reflected by said wafer;

comparing the intensity of light reflected by said wafer to the intensity of light reflected by said reflective surface having said known reflectivity;

using said comparison of the intensity of light reflected by said wafer to the intensity of light reflected by said reflective

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surface having said known reflectivity to correct for said absorption.

59. A method for measuring surface charge in a semiconductor wafer during semiconductor processing, said method comprising the steps of:

conveying said wafer such that a surface of said wafer is substantially parallel to a surface photovoltage electrode of a head assembly during said semiconductor processing;

exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency;

detecting with said surface photovoltage electrode a surface photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source; and

calculating the surface charge density from said induced surface photovoltage.

60. A method for measuring doping concentration in a semiconductor wafer during semiconductor processing, said method comprising the steps of:

creating an inversion layer in said wafer;

conveying said wafer such that a surface of said wafer is substantially parallel to a surface photovoltage electrode of a head assembly during said semiconductor processing;

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exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency;

detecting with said surface photovoltage electrode a surface photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source; and

calculating said doping concentration from said induced surface photovoltage.

61. A method for measuring carrier lifetime in a semiconductor wafer during semiconductor processing, said method comprising the steps of:

forming an inversion layer at a surface of said wafer;

conveying said wafer such that said surface of said wafer is substantially parallel to a surface photovoltage electrode of a head assembly during said semiconductor processing;

exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency;

detecting with said surface photovoltage electrode a photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source; and

calculating said carrier lifetime concentration from said induced surface photovoltage.

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62. A method for measuring conductivity type in a semiconductor wafer during semiconductor processing, said method comprising the steps of:

forming an inversion layer at a surface of said wafer;

conveying said wafer such that said surface of said wafer is substantially parallel to a surface photovoltage electrode of a head assembly during said semiconductor processing;

exposing at least a portion of said semiconductor wafer to light of a predetermined wavelength and modulated at a predetermined frequency;

detecting with said surface photovoltage electrode a photovoltage induced at the surface of said semiconductor wafer in response to said light from said modulated light source; and

calculating said conductivity from said induced surface photovoltage.

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